Shock Front Structure Measured by Broadband Proton Radiography

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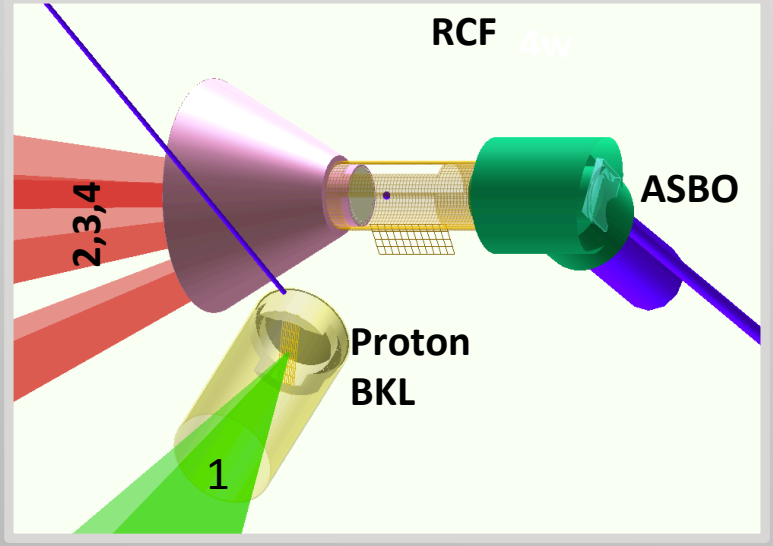

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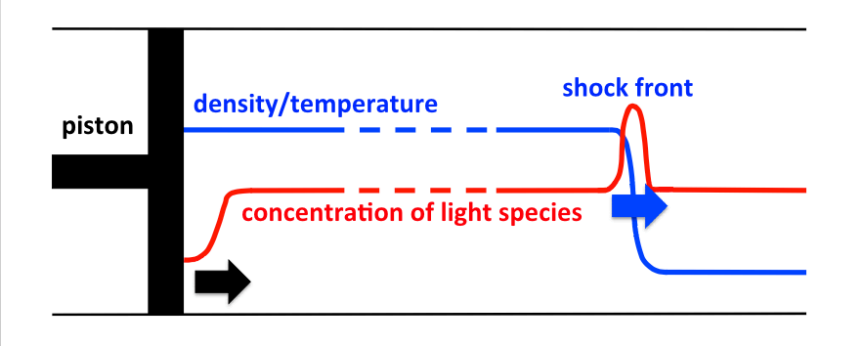
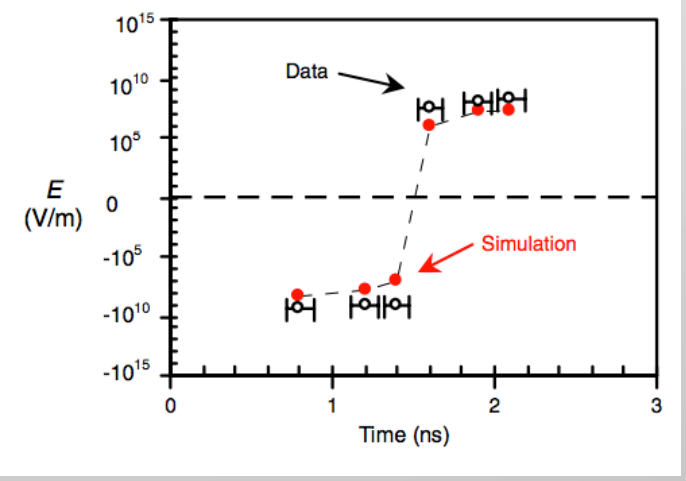
Kinetic effect plays an important role in plasma physics of ICF

- Transition from hydrodynamic-like to strong kinetic regime occurs in implosion experiment as initial filling density decrease. *[Rosenberg, M. J., et al. Phys. Rev. lett. 112.18 (2014): 185001]*
- First observation of electric fields at shock front was achieved in an ICF implosion experiment. *[C.K. Li, et al., Phys. Rev. Lett .100, 225001 (2008)]*

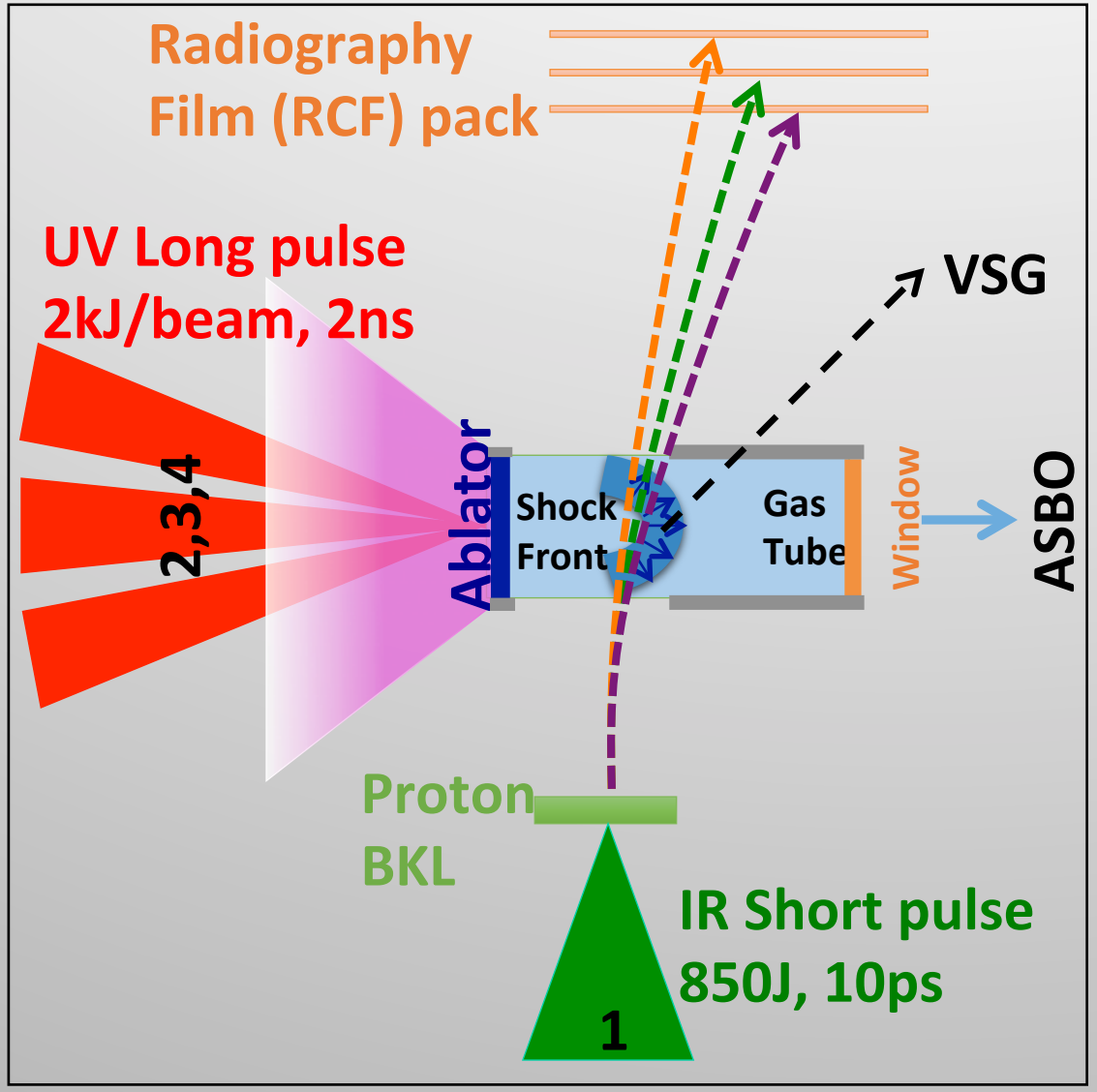


Bellei, C., and P. A. Amendt. " *Physical Review E* 90.1 (2014): 013101.



An Experiment using broadband TNSA proton radiography film to study shock front structure in quasi-planar geometry was developed on EP.

Shock front structure measured by broadband proton radiography and variable line spaced grating spectrometer

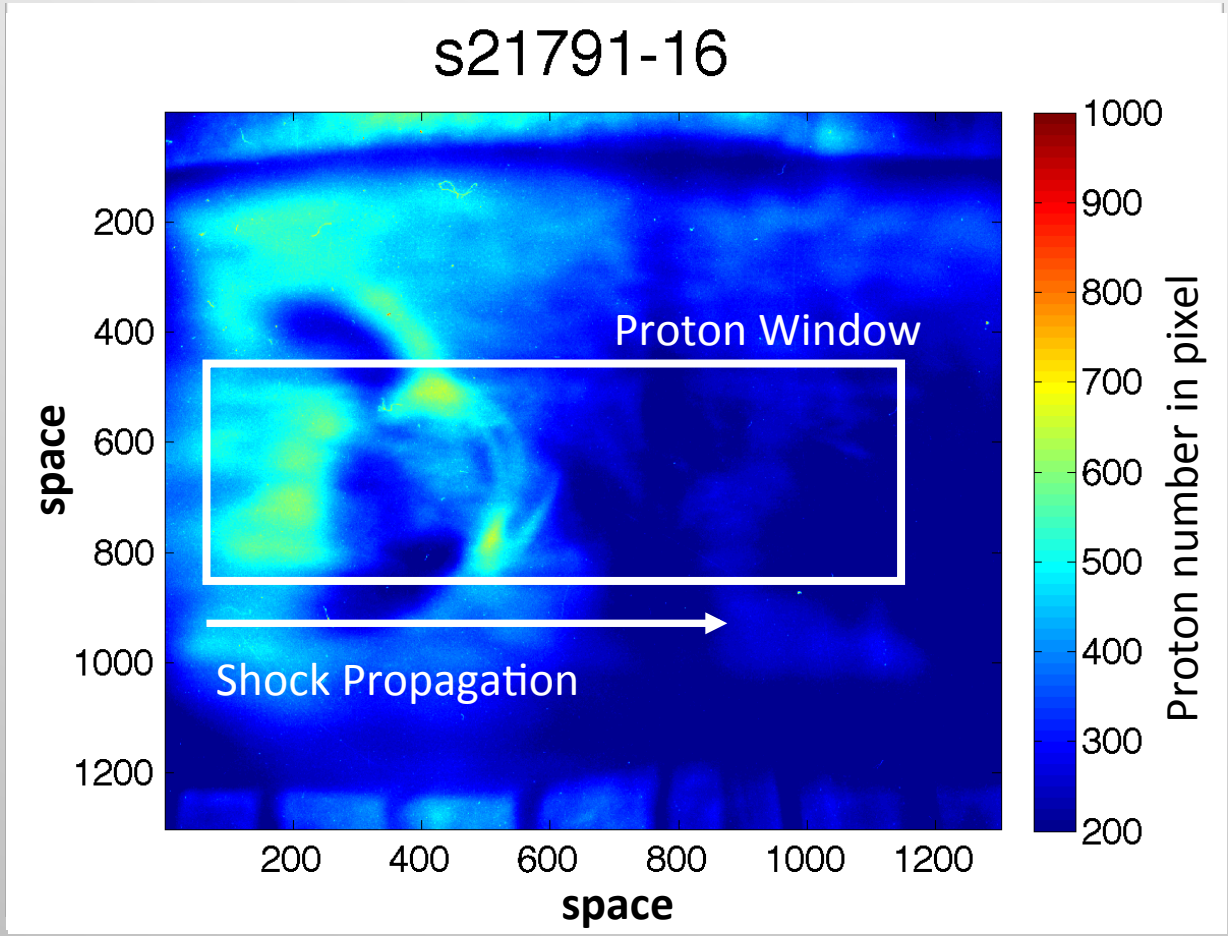


Targets were filled with either pure He or Mixture of He and 7% Ne at either 3 atm or 1 atm.

Beam	Energy/beam	Pulse
2, 3, 4	2.0kJ at 2ns, 400um spot size	2ns
1	850 J	10ps

Diagnostic
Radiography module
VSG (variable line spaced grating)
ASBO/SOP

Two proton rings were observed at shock front. One is due to density scattering and the other is due to E-field deflection

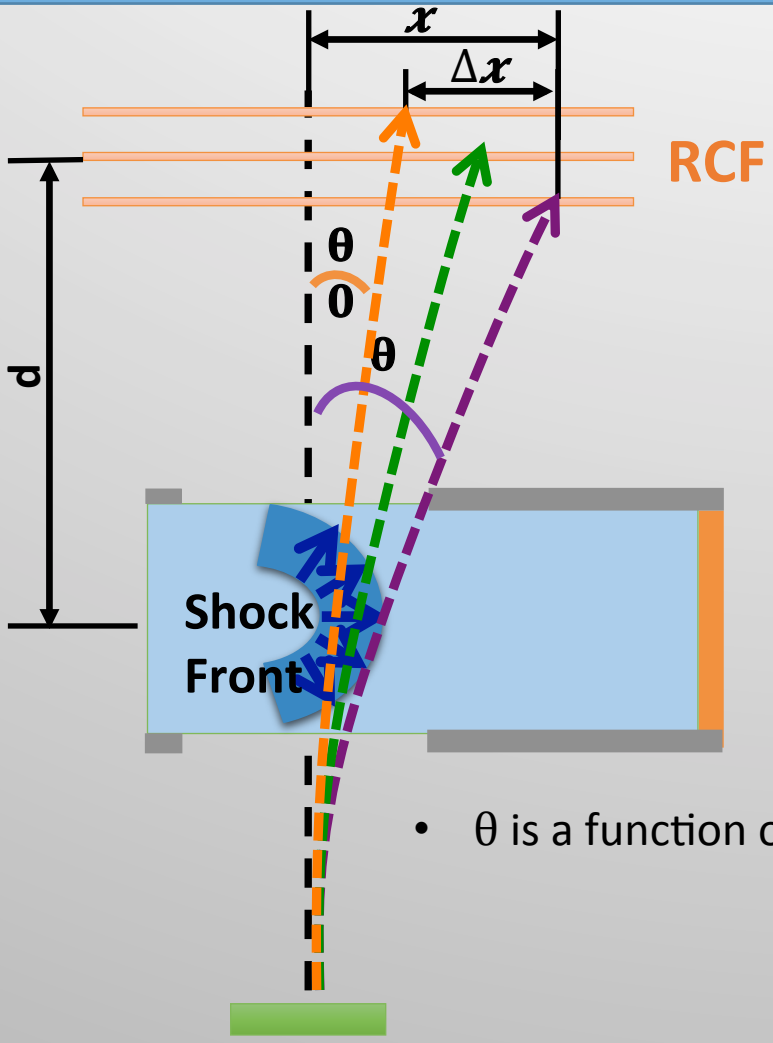


RCF presents a broadband proton energy data from 3.42 MeV to 22.47 MeV

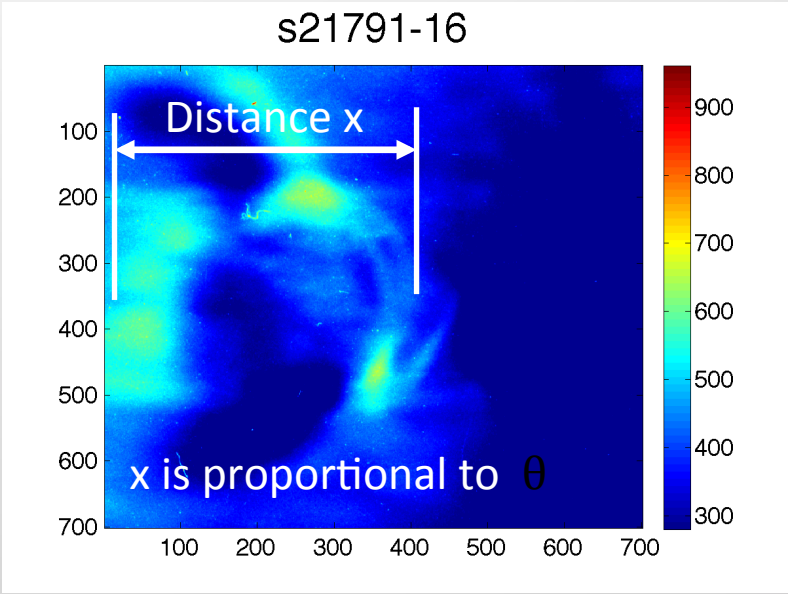
Layer #		Proton Energy(MeV)
	100um Al	
1	HD	3.42
6	HD	8.19
12	HD	11.83
18	HD	14.71
24	MD	19.23
28	MD	22.47

- Double rings feature is clear between around 10 MeV and 20 MeV.
- As energy continue to increase, two rings turn into one because high energy protons go trough E-field straight and can not resolve the two structure.

A model is used to calculate electric potential based on energy dependent deflection



- θ is a function of $\mathcal{E}$

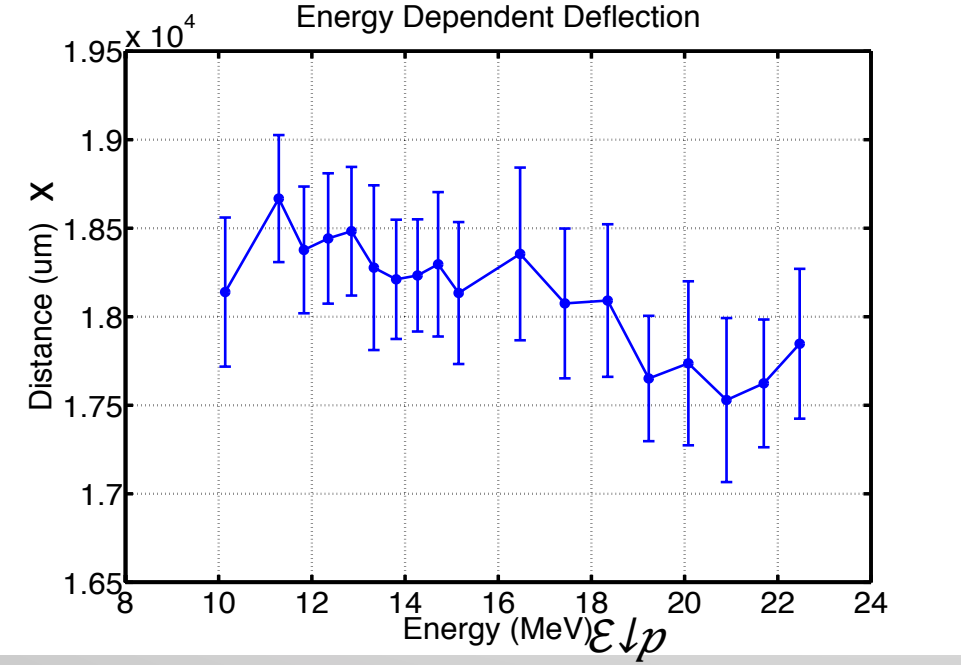


$$\frac{\Delta x}{d} = \Delta\theta = \theta - \theta_0 = \frac{v_\perp}{v_\parallel} - \frac{v_{\perp 0}}{v_{\parallel 0}} = \sqrt{\frac{\Phi}{\mathcal{E}_p}} - \sqrt{\frac{\Phi}{\mathcal{E}_{p0}}}$$

$$\frac{1}{2}mv_\parallel^2 = \mathcal{E}_p \qquad \frac{1}{2}mv_\perp^2 = \Phi$$

$$\Delta x = d\sqrt{\Phi(MeV)}\left(\frac{1}{\sqrt{\mathcal{E}_p}} - \frac{1}{\sqrt{\mathcal{E}_{p0}}}\right)$$ constant

Electric potential of 8KV is got from the calculation
RCF data also provides shock velocity measurement

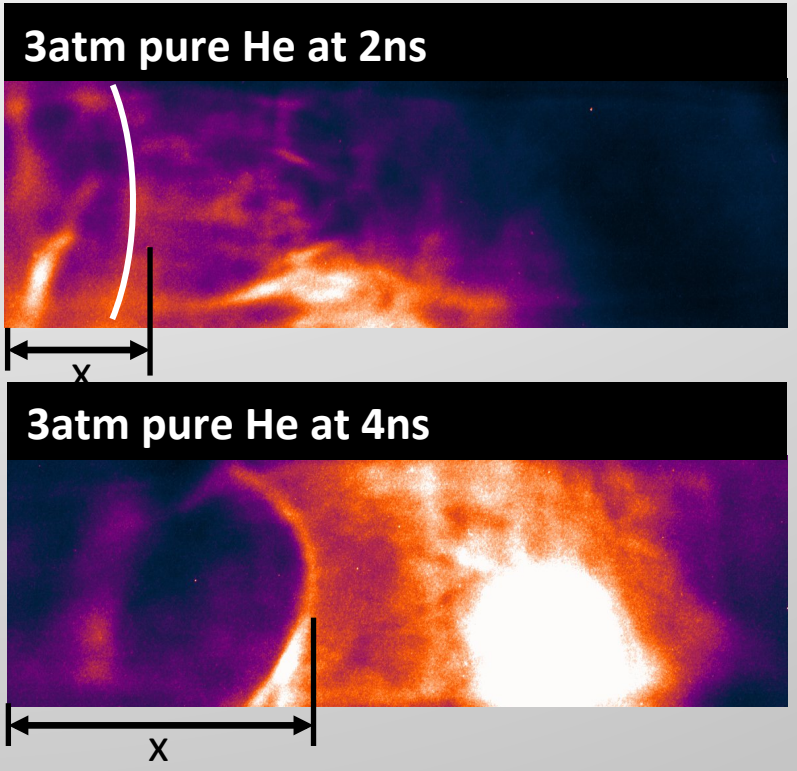


- Films for proton energy below 10 MeV were not very useful because of the low contrast.
- As Proton energy increase, the deflection of the 2nd accumulation ring decrease.

$$\Delta x = d\sqrt{\Phi(MeV)}\left(\frac{1}{\sqrt{\mathcal{E}_p}} - \frac{1}{\sqrt{\mathcal{E}_{p0}}}\right) \quad \text{constant}$$

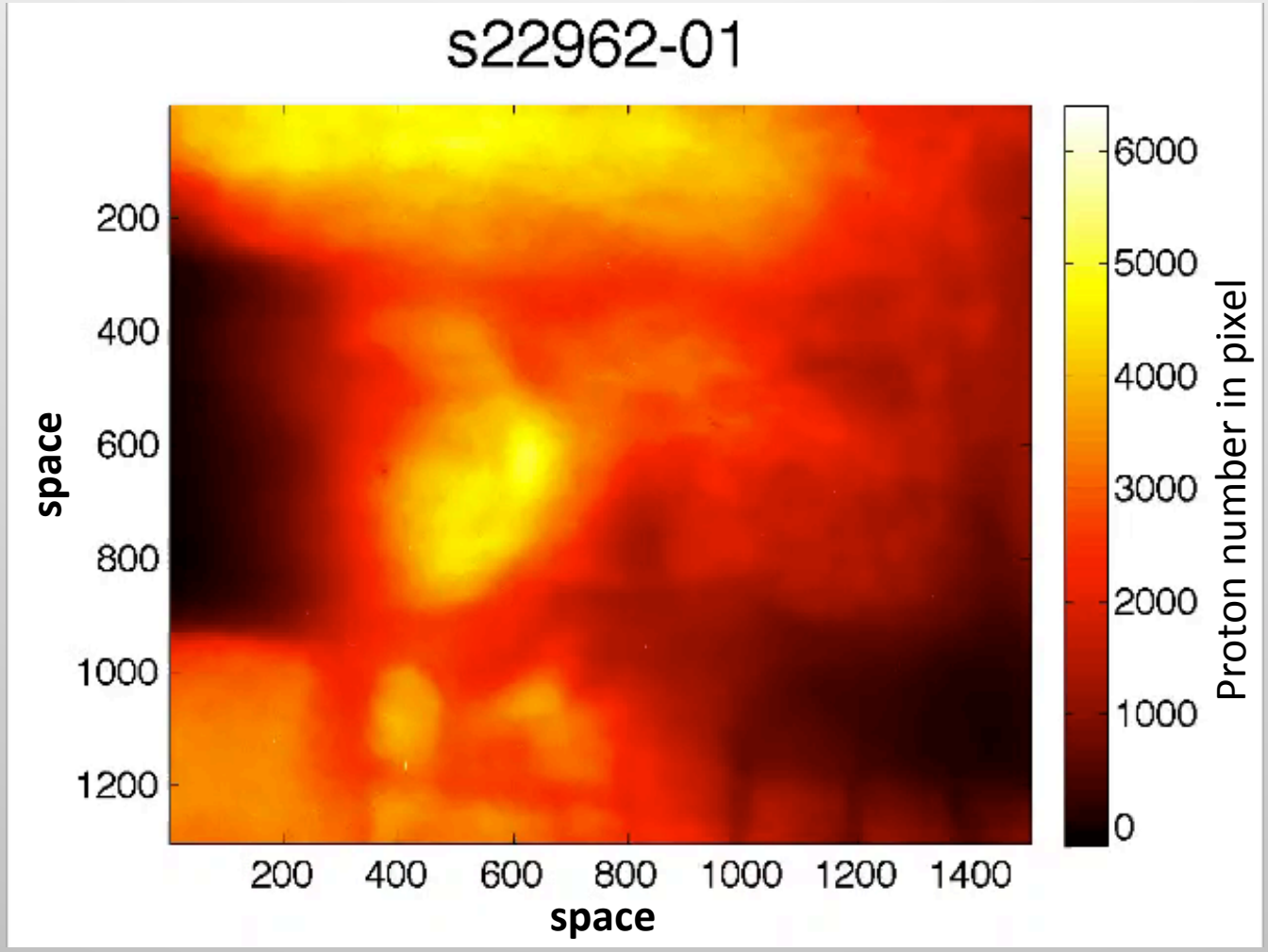
Φ ~ 8 KV

Shock speed calculation



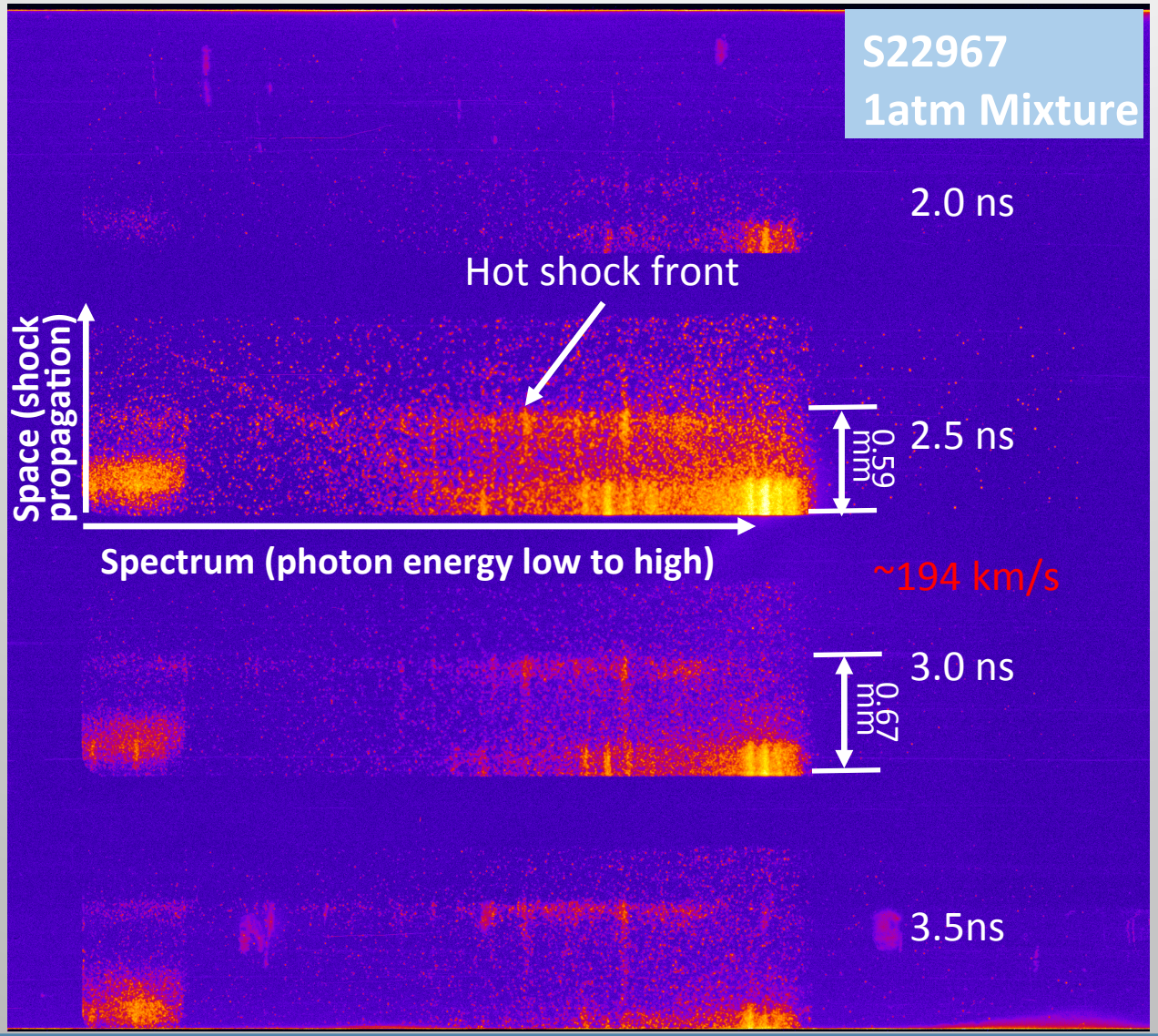
- Two shots with identical condition probed at different time.
- Shock speed between 2ns and 4ns is in the range of 170km/s to 290km/s.

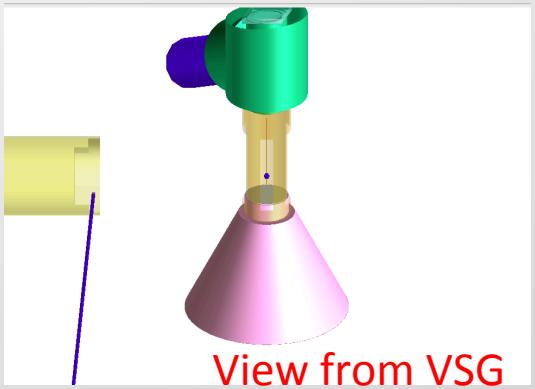
Prominent RCF data are obtained from recent shot of lower initial density



- Shot for the RCF was with 1 atm pure Helium.
- Double rings feature at shock front is very clear to see.

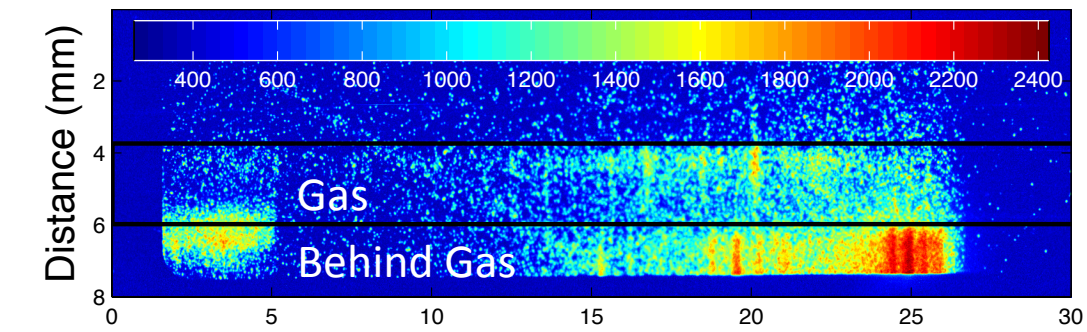
Variable Spacing Grating spectrometer (VSG) data give shock velocity measurement

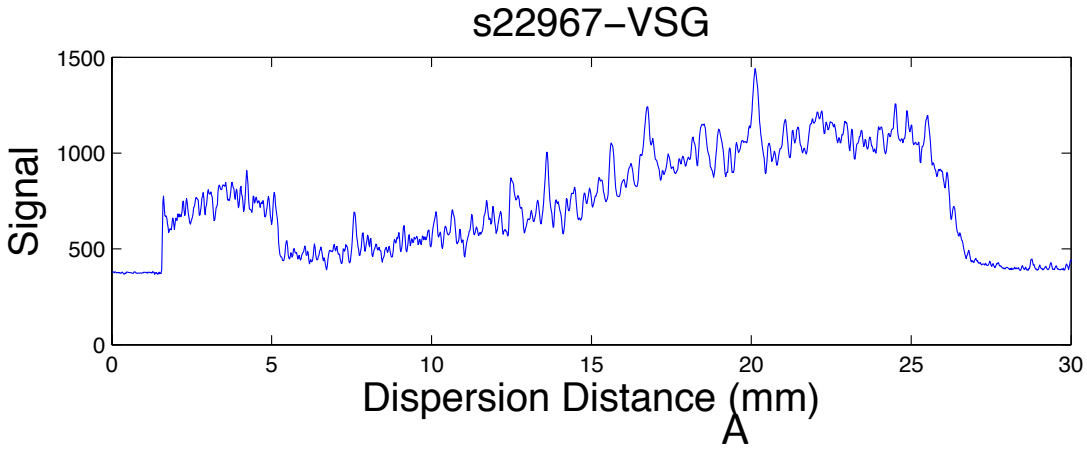




- Clear shock frontend and its movement at different time step is observed by VSG.
- Detected shock speed is in consistency with that from RCF.

VSG line emission data give temperature estimation behind the shock front





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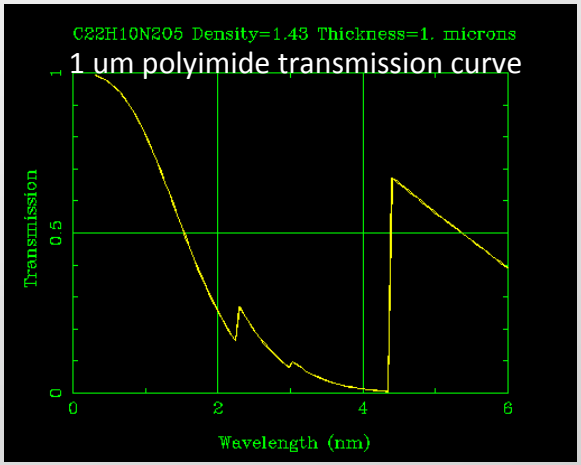


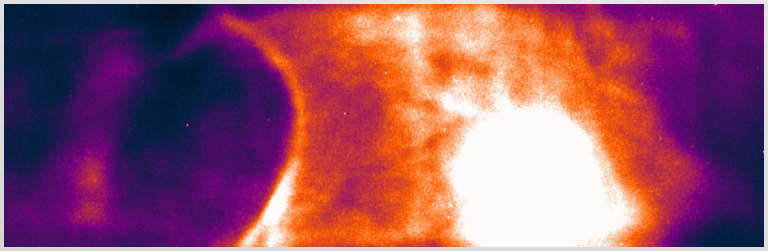
1 um polyimide transmission curve

- 1um kapton (C, N,O) window was applied for VSG. The general shape of the dispersion plot is caused by the Kapton transmission rate.

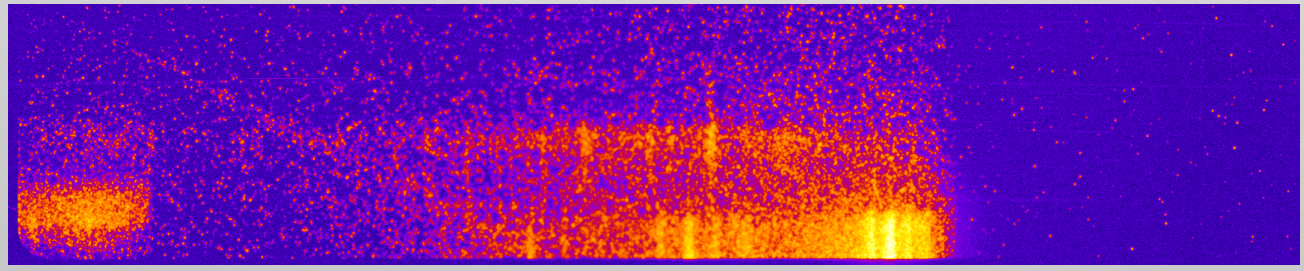
- Shock temperature can be constrained from the presence of O VIII line and absence of Ne X line.

Summary

- A successful platform for studying fields in shocks by proton radiography has been developed on Omega EP.
- RCF data give potential and shock speed measurement.



- VSG data give shock speed measurement and temperature estimation.



- Further experiment is on schedule in August. More mixture shots will be performed for that shot day.
- LSP simulation will be used to benchmark the experiment data in the future.

The end

Thanks!